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MINISTRY OF AGRICULTURE AND FORESTRY
GENERAL DIRECTORATE OF WATER MANAGEMENT

Water Efficiency Campaign

Water Efficiency
Guidance Documents Series

STEAM AND CLIMATE CONTROL SUPPLY

NACE CODE: 35.30

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Contents

Abbreviations

WTP	Wastewater Treatment Plant
EU	European Union
SSM	Suspended Solid Matter
BREF	Best Available Techniques Reference Document
EMS	Environmental Management System
MoEUCC	Republic of Turkey Ministry of Environment, Urbanization and Climate Change
NOM	Natural Organic Matter
EMAS	Eco Management and Audit Program Directive
EPA	United States Environmental Protection Agency
IPPC	Industrial Pollution Prevention and Control
ISO	International Organization for Standardization
BAT	Best Available Techniques
NACE	Statistical Classification of Economic Activities
GSWM	General Directorate of Water Management
RO	Reverse Osmosis
MAF	Ministry of Agriculture and Forestry of the Republic of Turkey
TurkStat	Turkish Statistical Institute
NF	Nanofiltration
MF	Microfiltration
UF	Ultrafiltration
GW	Groundwater
SW	Surface Water

1 Introduction

Türkiye is located in the Mediterranean basin, where the effects of global climate change are felt intensely, and is considered to be among the regions that will be most affected by the negative effects of climate change. Projections on how water resources in basins will be affected in the future due to climate change show that water resources may decrease by up to 25 per cent in the next hundred years.

For the year 2022, the annual amount of water available per capita in Türkiye is 1,313 m^3, and it is expected that the annual amount of water available per capita will fall below 1,000 cubic meters after 2030 due to human pressures and the effects of climate change. If the necessary measures are not taken, it is obvious that Türkiye will become a country suffering from water scarcity in the very near future and will bring many negative social and economic consequences. As can be understood from the results of future projections, the risk of drought and water scarcity awaiting our country necessitates the efficient and sustainable use of our existing water resources.

The concept of water efficiency can be defined as *"using the least amount of water in the production of a product or service"*. The water efficiency approach is based on the rational, sharing, equitable, efficient and effective use of water in all sectors, especially in drinking water, agriculture, industry and household use, in a way that protects water in terms of quantity and quality and takes into account not only the needs of humans but also the needs of all living things with ecosystem sensitivity.

With the increasing demand for water resources, changes in precipitation and temperature regimes as a result of climate change, increasing population, urbanization and pollution, fair and balanced allocation of usable water resources among users is becoming more and more important every day. Thus, it has become a necessity to create a road map based on efficiency and optimization in order to protect and use limited water resources through sustainable management practices.

In the sustainable development vision set by the United Nations, aspects such as efficient, equitable, and sustainable use of resources—especially water—environmentally friendly production, and consumption mindful of future generations are addressed within the scope of the Millennium Development Goals, specifically Goal 7: Ensure Environmental Sustainability, as well as within the Sustainable Development Goals, specifically Goal 9: Industry, Innovation, and Infrastructure, and Goal 12: Responsible Consumption and Production.

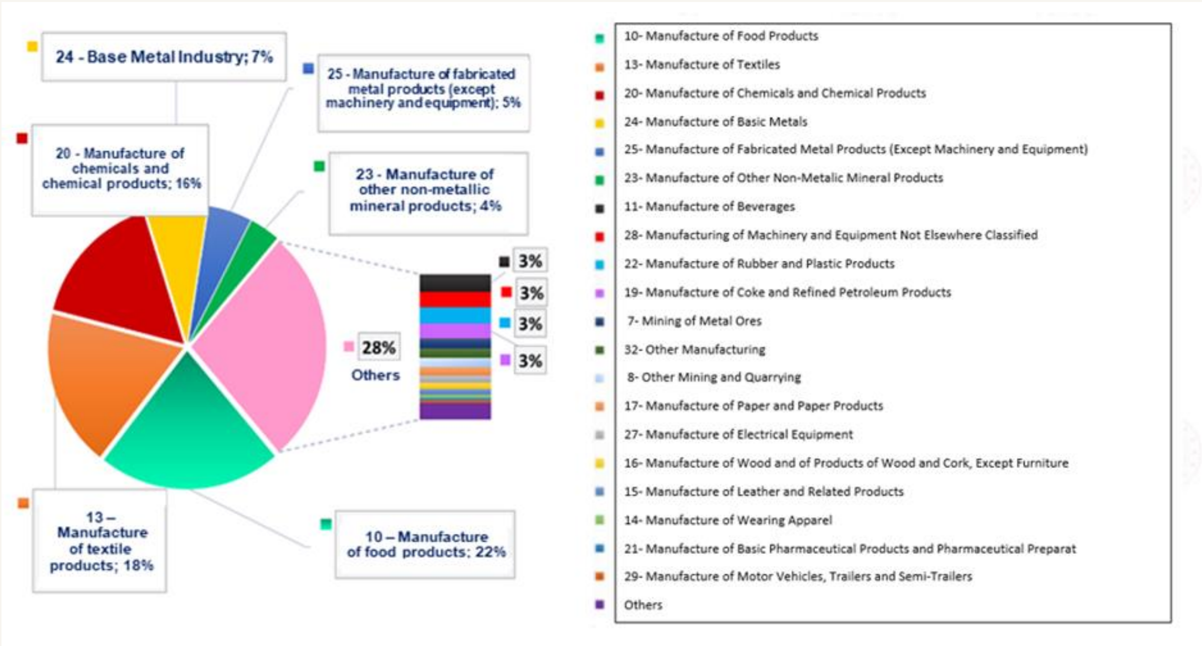
Within the framework of the European Green Deal, which member countries have agreed upon with goals such as achieving a carbon-neutral target, implementing a clean and circular economy model, promoting efficient resource use, and reducing environmental impacts, our country's European Green Deal Action Plan outlines actions emphasizing water and resource efficiency in production and consumption, particularly in the industrial sector and various other areas.

“The Industrial Emissions Directive (IED)”, one of the most critical components of European Union environmental legislation for industry, includes measures to control, prevent, or reduce emissions and discharges into air, water, and soil from industrial activities through an integrated approach. The Directive introduces Best Available Techniques (BAT) to systematize the applicability of clean production processes and address implementation challenges. BAT represents the most effective techniques for ensuring a high level of environmental protection, taking into account both costs and benefits. In compliance with the Directive, Reference Documents (BAT-BREF) have been prepared for each sector, detailing BATs. These BREF documents present BATs within a general framework that includes best management practices, general preventive techniques, chemical use and management, techniques for various production processes, wastewater management, emission management, and waste management.

The Ministry of Agriculture and Forestry, General Directorate of Water Management carries out activities aimed at disseminating efficient practices in urban, agricultural, industrial and individual water use and raising social awareness. Water efficiency action plans addressing all sectors and stakeholders have been prepared within the scope of the ***"Water Efficiency Strategy Document and Action Plan (2023-2033) within the Framework of Adaptation to a Changing Climate"***, which entered into force with the Presidential Circular No. 2023/9. In the Industrial Water Efficiency Action Plan, a total of 12 actions have been determined for the period 2023-2033 and responsible and relevant institutions have been assigned for these actions. Within the scope of the Action Plan, the General Directorate of Water Management is responsible for carrying out studies to determine specific water use ranges and quality requirements on the basis of sub-sectors in industry, organizing technical training programmes and workshops on sectoral basis and preparing water efficiency guidance documents.

On the other hand, with the ***"Industrial Water Use Efficiency Project by NACE Codes"*** carried out by the General Directorate of Water Management of the Ministry of Agriculture and Forestry, sectoral best techniques specific to our country were determined within the scope of the studies for improving water efficiency in industry. As a result of the study, sectoral guidance documents and action plans categorized by NACE codes, including the measures recommended for improving water use efficiency in sectors with high water consumption operating in Türkiye, were prepared.

As in the world, the sectors with the highest share in water consumption in our country are food, textile, chemical and basic metal sectors. Within the scope of the studies, field visits were carried out in enterprises representing 152 sub-sectors in 35 main sectors, mainly food, textile, chemical and basic metal industries, representing production areas with different capacities and diversity within the scope of NACE Codes operating in our country and with high water consumption, and data on water supply, sectoral water use, wastewater generation, recycling were obtained and information was provided on the best available techniques (BAT) and their reference documents (BREF) published by the European Union, water efficiency, clean production, water footprint, etc.



Sectoral distribution of water use in industry in Türkiye

As a result of the studies, specific water consumption and potential saving rates for the processes of enterprises for 152 different 4-digit NACE codes with high water consumption were determined, and water efficiency guidance documents were prepared by taking into account the EU best available techniques (BAT) and other cleaner production techniques. Within the guidelines, 500 techniques (BAT) for water efficiency; (i) Good Management Practices, (ii) General Measures, (iii) Measures Related to Auxiliary Processes and (iv) Sector Specific Measures.

Within the scope of the project, environmental benefits, operational data, technical specifications-requirements and applicability criteria were taken into consideration during the determination of BATs for each sector. In the determination of BATs, not only BREF documents were not limited, but also different data sources such as current literature data on a global scale, real case analyses, innovative practices, reports of sector representatives were examined in detail and sectoral BAT lists were created. In order to evaluate the suitability of the BAT lists created for the local industrial infrastructure and capacity of our country, the BAT lists prepared specifically for each NACE code were prioritised by the enterprises by scoring them on the criteria of water saving, economic savings, environmental benefit, applicability, cross-media impact and the final BAT lists were determined using the scoring results. Water and wastewater data of the facilities visited within the scope of the project and the final BAT lists, which were prioritised by sectoral stakeholders and determined by taking into account the local dynamics specific to our country, were used to create sectoral water efficiency guides on the basis of NACE code.

2 Scope of the Study

Guidance documents prepared within the scope of water efficiency measures in industry cover the following main sectors:

- Crop and animal production and hunting and related service activities (including sub-production area represented by 6 four-digit NACE codes)
- Fisheries and aquaculture (including sub-production area represented by 1 four-digit NACE Code)
- Coal and lignite extraction (including sub-production area represented by 2 four-digit NACE codes)
- Service activities in support of mining (including sub-production area represented by 1 four-digit NACE Code)
- Metal ores mining (including the sub-production area represented by 2 four-digit NACE codes)
- Other mining and quarrying (including the sub-production area represented by 2 four-digit NACE codes)
- Manufacture of food products (including 22 sub-production areas represented by four-digit NACE codes)
- Manufacture of beverages (including the sub-production area represented by 4 four-digit NACE codes)
- Manufacture of tobacco products (including sub-production area represented by 1 four-digit NACE Code)
- Manufacture of textile products (including 9 sub-production areas represented by four-digit NACE codes)
- Manufacture of articles of clothing (including sub-production area represented by 1 four-digit NACE Code)
- Manufacture of leather and related products (including sub-production area represented by 3 four-digit NACE codes)
- Manufacture of wood, wood products and cork products (except furniture); manufacture of articles made of thatch, straw and similar materials (including sub-production area represented by 5 four-digit NACE Codes)
- Manufacture of paper and paper products (including sub-production area represented by 3 four-digit NACE codes)
- Manufacture of coke and refined petroleum products (including sub-production area represented by 1 four-digit NACE Code)
- Manufacture of chemicals and chemical products (including 13 sub-production areas represented by four-digit NACE codes)
- Manufacture of basic pharmaceutical products and pharmaceutical ingredients (including sub-production area represented by 1 four-digit NACE Code)
- Manufacture of rubber and plastic products (including sub-production area represented by 6 four-digit NACE codes)
- Manufacture of other non-metallic mineral products (including 12 sub-production areas represented by four-digit NACE codes)
- Basic metal industry (including 11 sub-production areas represented by four-digit NACE codes)
- Manufacture of fabricated metal products (except machinery and equipment) (including 12 sub-production areas represented by four-digit NACE codes)
- Manufacture of computers, electronic and optical products (including sub-production area represented by 2 four-digit NACE codes)
- Electrical equipment manufacturing (including sub-production area represented by 7 four-digit NACE codes)

- Manufacture of machinery and equipment not elsewhere classified (including sub-production area represented by 8 four-digit NACE codes)
- Manufacture of motor vehicles, trailers (semi-trailers) and semi-trailers (semi-trailers) (including sub-production area represented by 3 four-digit NACE codes)
- Manufacture of other transport equipment (including sub-production area represented by 2 four-digit NACE codes)
- Other manufacturing (including 2 sub-production areas represented by four-digit NACE codes)
- Installation and repair of machinery and equipment (including sub-production area represented by 2 four-digit NACE codes)
- Electricity, gas, steam and ventilation system production and distribution (including sub-production area represented by 2 four-digit NACE codes)
- Waste collection, reclamation and disposal activities; recovery of materials (including sub-production area represented by 1 four-digit NACE Code)
- Construction of non-building structures (including sub-production area represented by 1 four-digit NACE Code)
- Warehousing and supporting activities for transport (including sub-production area represented by 1 four-digit NACE Code)
- Accommodation (including sub-production area represented by 1 four-digit NACE Code)
- Educational Activities (Higher Education Campuses) (including sub-production area represented by 1 four-digit NACE Code)
- Sporting activities, leisure and recreation activities (including sub-production area represented by 1 four-digit NACE Code)

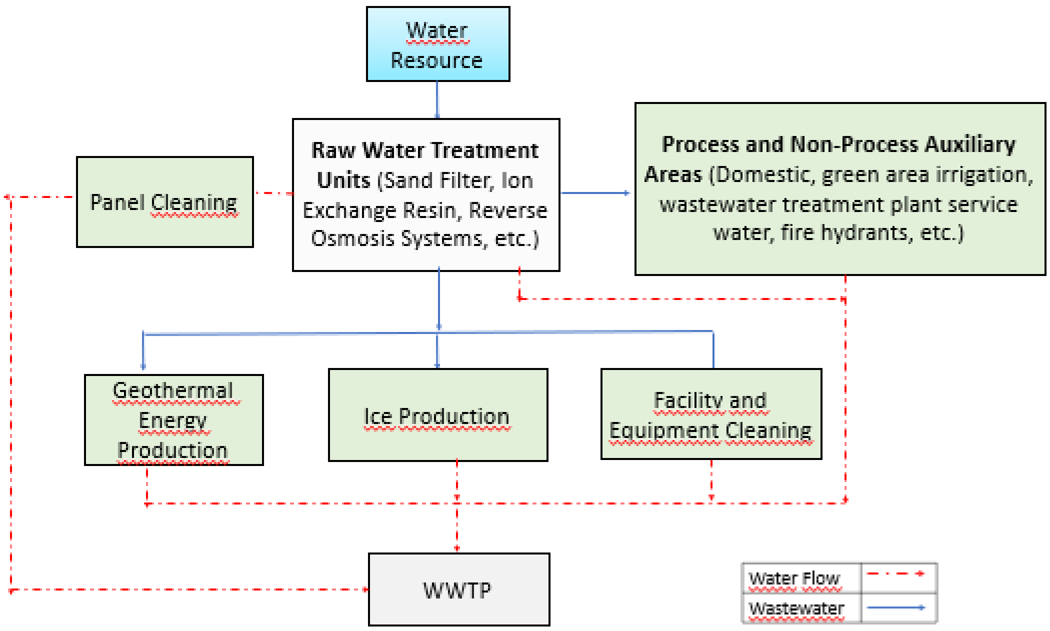
Electricity, gas, steam and ventilation system production and distribution

Under the electricity, gas, steam and ventilation system production and distribution sector, the sub-production branches for which guidance documents were prepared are as follows

35.11	Electric power generation
35.30	Steam and air conditioning supply

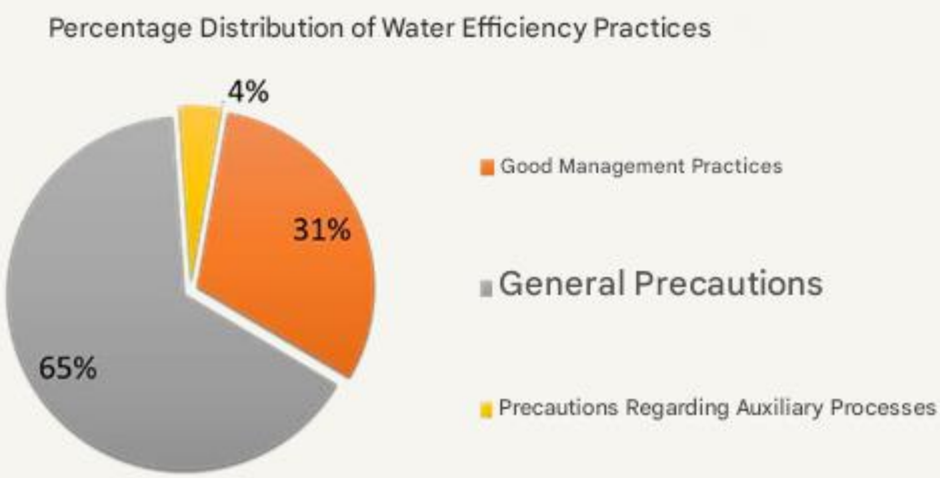
2.1 Steam and Air Conditioning Supply (NACE 35.30)

Water Flow Diagram for the Steam and Climate Control Supply Sector



	Minimum	Maximum
Specific Water Consumption of Facilities Visited Within the Project Scope (L/kWh)	31,03	
Reference Specific Water Consumption (L/kWh)	No reference specific water consumption value is available.	

Percentage Distribution of Water Efficiency Practices



Steam, hot water and geothermal energy are produced in the steam and climate control supply sector. In these facilities, water supplied from geothermal wells is reinjected into groundwater after energy production. In addition to geothermal plants, micro and small scale moulded ice and dry ice production factories are also operating in the steam and climate control supply sector. In ice production facilities, the water supplied is converted into ice.

Although water is used in the production processes in the steam and climate control supply sector in the production of geothermal energy, the water is re-injected into the groundwater and no consumption is realised. In ice production facilities, a water consumption is realised since water is added to the product content. Water is also consumed in cooling systems. If there are raw water preparation units such as activated carbon filter, ion exchange resin, reverse osmosis, which are used to produce soft water to be used in production processes in the sector, significant water consumption is also realised for filter washing, resin regeneration and membrane cleaning processes.

There is no reference specific consumption value in the steam and air conditioning supply sector. The specific water consumption of the production branch analysed within the scope of the study (geothermal energy production) is 31.03 L/watt. With the implementation of good management practices, measures in the form of general measures and measures related to auxiliary processes, it is possible to achieve water savings of 49 - 61% in the sector.

35.30 Priority water efficiency implementation techniques recommended within the scope of Steam and Climate Control Supply NACE code are presented in the table below.

NACE Code	NACE Code Description		Prioritised Sectoral Water Efficiency Techniques
35.30	Steam and climate control supply		**Good Management Practices**
		1.	Establishment of environmental management system
		2.	Preparation of water flow diagrams and mass balances for water
		3.	Preparing a water efficiency action plan to reduce water use and prevent water pollution
		4.	Providing technical trainings to the staff for the reduction and optimisation of water use
		5.	Good production planning to optimise water consumption
		6.	Determination of water efficiency targets
		7.	Monitoring the quantity and quality of water used in production processes and auxiliary processes and the wastewater generated and adapting this information to the environmental management system
			General Water Efficiency BATs
		1.	Minimising spillages and leakages
		2.	Use of automatic hardware and equipment (sensors, smart hand washing systems, etc.) to save water at water usage points such as showers/toilets etc.
		3.	Use of pressure washing systems for equipment cleaning, general cleaning, etc.
		4.	Avoiding the use of drinking water in production lines
		5.	Use of cooling water as process water in other processes
		6.	Identification and minimisation of water losses
		7.	Use of automatic control-close valves to optimise water use
		8.	Documented production procedures are kept and used by employees to prevent water and energy wastage
		9.	Optimising the frequency and duration of regeneration (including rinses) in water softening systems
		10.	Construction of closed storage and impermeable waste/scrap sites to prevent the transport of toxic or hazardous chemicals for the aquatic environment
		11.	Storage and storage of substances (such as oils, emulsions, binders) that pose a risk in the aquatic environment and prevention of their mixing with wastewater after use
		12.	Prevention of mixing of clean water flows with polluted water flows
		13.	Determination of wastewater flows that can be reused with or without treatment by characterising the wastewater quantities and qualities at all wastewater generation points
		14.	Use of closed loop water cycles in appropriate processes
		15.	Use of computer aided control systems in production processes

NACE Code	NACE Code Description		Prioritised Sectoral Water Efficiency Techniques
35.30	Steam and climate control supply	16.	Determination of the scope of reuse of washing and rinsing water
		17.	Separate collection and treatment of grey water in the plant and high water quality use in areas that do not require (green area irrigation, floor washing, etc.)
		18.	Implementation of time optimisation in production and arrangement of all processes to be completed as soon as possible
		19.	Collecting rainwater and utilising it as an alternative water source in facility cleaning or in suitable areas
			Precautions for Auxiliary Processes
		1.	Use of air cooling systems instead of water cooling in cooling systems
A total of 27 techniques have been proposed in this sector			

For Steam and Air Conditioning Supply NACE Code;

(i) Good Management Practices,
(ii) General Water Efficiency BATs and
(iii) Precautions for Auxiliary Processes are given under separate headings.

2.1.1 Good Management Practices

- ***Establishment of environmental management system***

Environmental Management Systems (EMS) include the organisational structure, responsibilities, procedures and resources required to develop, implement and monitor the environmental policies of industrial organisations. The establishment of an environmental management system improves the decision-making processes between raw materials, water and wastewater infrastructure, planned production process and different treatment techniques. Environmental management organises how resource supply and waste discharge demands can be managed with the highest economic efficiency, without compromising product quality and with the least possible impact on the environment.

The most widely used Environmental Management Standard is ISO 14001. Alternatives include the Eco Management and Audit Scheme Directive (EMAS) (761/2001). It has been developed for the assessment, improvement and reporting of the environmental performance of enterprises. It is one of the leading practices within the scope of eco-efficiency (cleaner production) in EU legislation and voluntary participation is provided (TUBITAK MAM, 2016; MAF, 2021). The benefits of establishing and implementing an Environmental Management System are as follows:

- Economic benefits can be obtained by improving business performance (Christopher, 1998).
- International Standards Organisation (ISO) standards are adopted to ensure greater compliance with global legal and regulatory requirements (Christopher, 1998).
- While the risks of penalties related to environmental responsibilities are minimised, the amount of waste, resource consumption and operating costs are reduced (Delmas, 2009).
- The use of internationally recognised environmental standards eliminates the need for multiple registrations and certificates for businesses operating in different locations around the world (Hutchens Jr., 2017).
- Especially in recent years, the improvement of the internal control processes of companies is also considered important by consumers. The implementation of environmental management systems provides a competitive advantage against companies that do not adopt the standard. It also contributes to the better position of organisations in international areas / markets (Potoski & Prakash, 2005).

The above-mentioned benefits depend on many factors such as the production process, management practices, resource utilisation and potential environmental impacts (MAF, 2021). Practices such as preparing annual inventory reports with similar content to the environmental management system and monitoring inputs and outputs in terms of quantity and quality in production processes can save 3-5% of water consumption (Öztürk, 2014). The total duration of the development and implementation phases of the EMS takes an estimated 8-12 months (ISO 14001 User Manual, 2015).

Industrial organisations also carry out studies within the scope of ISO 14046 Water Footprint Standard, an international standard that defines the requirements and guidelines for assessing and reporting water footprint. With the implementation of the relevant standard, it is aimed to reduce the use of fresh water required for production and environmental impacts. In addition, ISO 46001 Water Efficiency Management Systems Standard, which helps industrial organisations to save water and reduce operating costs, helps organisations to develop water efficiency policies by conducting monitoring, benchmarking and review studies.

- ***Providing technical trainings to personnel for the reduction and optimisation of water use***

  With this measure, water saving and water recovery can be achieved by increasing the training and awareness of the personnel, and water efficiency can be achieved by reducing water consumption and costs. In industrial facilities, problems related to high water consumption and wastewater generation may arise due to the lack of necessary technical knowledge of the personnel. For example, it is important that cooling tower operators, which represent a significant proportion of water consumption in industrial operations, are properly trained and have technical knowledge. Determination of water quality requirements in production processes, measurement of water and wastewater quantities, etc. It is also necessary for the relevant personnel to have sufficient technical knowledge (MAF, 2021). Therefore, it is important to provide training to staff on water use reduction, optimisation and water saving policies. Practices such as involving the staff in water saving studies, creating regular reports on the amount of water use before and after water efficiency initiatives, and sharing these reports with the staff support participation and motivation in the process. The technical, economic and environmental benefits to be obtained through staff training yield results in the medium or long term (TUBITAK MAM, 2016; MAF, 2021).

- ***Preparation of a water efficiency action plan to reduce water use and prevent water pollution***

  Preparation of an action plan including short, medium and long term actions to be taken in order to reduce the amount of water-wastewater in industrial facilities and prevent water pollution in terms of water efficiency is important. At this point, determination of water needs throughout the plant and in production processes, water quality requirements at the points of use, wastewater generation points and wastewater characterisation should be carried out (MAF, 2021). At the same time, it is necessary to determine the measures to be implemented to reduce water consumption, wastewater generation and pollution loads, to make their feasibility and to prepare action plans for the short-medium-long term. In this way, water efficiency and sustainable water use are ensured in the facilities (MAF, 2021).

- ***Determination of water efficiency targets***

  The first step in achieving water efficiency in industrial facilities is to define targets (MAF, 2021). To this end, a detailed water efficiency analysis based on processes must be conducted as a priority. This will help identify unnecessary water usages, water losses, incorrect practices affecting water efficiency, process losses, reusable water and wastewater sources that can be treated or untreated, and so on. It is also crucial to determine the water savings potential and water efficiency targets for each production process and the facility as a whole (MAF, 2021).

- ***Preparation of water flow diagrams and mass balances for water***

  Determination of water use and wastewater generation points in industrial plants, establishment of water-wastewater balances in production processes and auxiliary processes other than production processes constitute the basis of many good management practices in general. Establishing process profiles throughout the plant and on the basis of production processes facilitates the identification of unnecessary water use points and high water use points, evaluation of water recovery opportunities, process modifications and determination of water losses (MAF, 2021).

- ***Good production planning to optimise water consumption***

  In industrial production processes, planning by using the least process in the process from raw material to product is an effective practice for reducing labour costs, resource use costs and environmental impacts and ensuring efficiency (TUBITAK MAM, 2016; MAF, 2021). Production planning in industrial plants, taking into account the water efficiency factor, reduces water consumption and wastewater amount. Modification of production processes in industrial plants or combining some processes provides significant benefits in terms of water efficiency and time planning (MAF, 2021).

- ***Monitoring the water used in production processes and auxiliary processes and the wastewater generated in terms of quantity and quality and adapting this information to the environmental management system***

  In industrial facilities, resource use is present, and the inefficiencies and environmental problems resulting from resource consumption can stem from input-output flows. Therefore, it is essential to monitor the quantity and quality of water and wastewater used in production processes and auxiliary processes (TUBITAK MAM, 2016; MAF, 2021). Process-based quantity and quality monitoring, combined with other good management practices (such as staff training and establishing an environmental management system), can lead to reductions of 6-10% in energy consumption and up to 25% in water consumption and wastewater volumes (Öztürk, 2014).

The main stages for monitoring water and wastewater in terms of quantity and quality are as follows

- Use of monitoring equipment (such as counters) to monitor water, energy, etc. consumption on a process basis,
- Establishment of monitoring procedures,
- Determining the usage/exit points of all inputs and outputs (raw materials, chemicals, water, products, wastewater, sludge, solid waste, hazardous waste and by-products) related to the production process, monitoring, documenting, comparative evaluation and reporting in terms of quantity and quality,
- Monitoring raw material losses in production processes where raw materials are transformed into products and taking measures against raw material losses (MoEUCC, 2020e).

2.1.2 General Water Efficiency BATs

- ***Identification and minimisation of water losses***

In industrial production processes, water losses occur in equipment, pumps, and piping systems. First, water losses should be detected, and regular maintenance of equipment, pumps, and piping should be conducted to keep them in good condition and prevent leaks (IPPC BREF, 2003). Regular maintenance procedures should particularly focus on the following aspects:

- Inclusion of pumps, valves, level switches, pressure and flow regulators in the maintenance checklist.
- Conducting inspections not only in the water system but also specifically in heat transfer and chemical distribution systems, as well as broken and leaking pipes, barrels, pumps, and valves.
- Regular cleaning of filters and piping.
- Calibration of measurement equipment, such as chemical measurement and distribution devices, thermometers, etc., along with routine checks and monitoring at specified intervals (IPPC BREF, 2003).

Effective maintenance, repair, cleaning, and loss control practices can achieve savings in water consumption ranging from 1% to 6% (Öztürk, 2014).

- ***Minimising spillages and leakages***

Both raw material and water losses can occur due to spills and leaks in enterprises. In addition, if wet cleaning methods are used to clean the areas where spillage occurs, water consumption, wastewater amounts and pollution loads of wastewater may also increase (MAF, 2021). In order to reduce raw material and product losses, spill and splash losses are reduced by using splash guards, flaps, drip trays, sieves (IPPC BREF, 2019).

- ***Use of pressure washing systems for equipment cleaning, general cleaning, etc.***

Water nozzles are widely used in equipment plant cleaning. Effective results can be achieved by using correctly placed, appropriate nozzles to reduce water consumption and wastewater pollution loads. The use of active sensors and nozzles at points where high water consumption occurs and where possible is very important in terms of efficient use of water. It is possible to achieve significant water savings by replacing mechanical equipment with pressurised nozzles (TUBITAK MAM, 2016). Reducing water consumption, wastewater generation and wastewater pollution load through the use of water pressure optimised nozzles in technically appropriate processes are the main environmental benefits of the application.

- ***Avoiding the use of drinking water in production lines***

  In different sub-sectors of the manufacturing industry, waters with different water quality can be used for production purposes. In industrial plants, raw water supplied from groundwater sources is generally used in production processes after treatment. However, in some cases, although it is costly in production processes, drinking water can be used directly or raw water is disinfected with chlorinated compounds and then used in production processes. These waters containing residual chlorine can react with organic compounds (natural organic substances (DOM)) in water in production processes and form disinfectant by-products harmful to living metabolisms (Özdemir & Toröz, 2010; Oğur et al.) The use of drinking water containing residual chlorine compounds or raw water disinfected with chlorinated compounds should be avoided as much as possible. Highly oxidising disinfection methods such as ultraviolet (UV), ultrasound (US) or ozone can be used instead of chlorine disinfection for disinfection of raw water. In order to increase the technical, economic and environmental benefits of the application, the determination and use of the water quality parameters required in each production process helps to reduce unnecessary water supply and treatment costs. With this application, it is possible to reduce water, energy and chemical costs (TUBITAK MAM, 2016).

- ***Use of cooling water as process water in other processes***

  Water cooling systems are widely used in processes where thermal energy is used intensively and cooling is required. It is possible to recover heat by using heat exchangers in cooling water return, prevent contamination of cooling water, and save water and energy by increasing cooling water return rates (TUBITAK MAM, 2016; MAF, 2021). In addition, in case of separate collection of cooling water, it is generally possible to use the collected water for cooling purposes or to reuse it in appropriate processes (EC, 2009). Reuse of cooling water can save 2-9% of total water consumption (Greer et al., 2013). Energy consumption can be saved up to 10% (Öztürk, 2014; MAF, 2021).

- ***Use of automatic control-close valves to optimise water use***

  Monitoring and controlling water consumption using flow control devices, meters and computer-aided monitoring systems provide significant technical, environmental and economic advantages (Öztürk, 2014). Monitoring the amount of water consumed in the plant and in various processes prevents water losses (TUBITAK MAM, 2016). It is necessary to use flow meters and counters in the plant in general and in production processes in particular, to use automatic shut-off valves and valves in continuously operating machines, and to develop monitoring-control mechanisms according to water consumption and some determined quality parameters by using computer-aided systems (TUBITAK MAM, 2016). With this application, it is possible to save up to 20-30% of water consumption on process basis (DEPA, 2002; LCPC, 2010; IPPC BREF, 2003). By monitoring and controlling water consumption on a process basis, 3-5% savings can be achieved in process water consumption (Öztürk, 2014).

- ***Documented production procedures are kept and used by employees to prevent water and energy wastage***

  In order to ensure efficient production in an enterprise, effective procedures should be implemented to identify and evaluate potential problems and resources and to control production stages (Ayan, 2010). Determining and implementing appropriate procedures in production processes ensures more efficient use of resources (such as raw materials, water, energy, chemicals, personnel and time) and ensures reliability and quality in production processes (Ayan, 2010). The existence of documented production procedures in production processes contributes to the evaluation of business performance and the development of the ability to develop immediate reflexes to solve problems (TUBITAK MAM, 2016; MAF, 2021). Effective implementation and monitoring of the procedures created specifically for production processes is one of the most effective ways to ensure product quality, receive feedback and develop solutions (Ayan, 2010). Documentation, effective implementation and monitoring of production procedures is a good management practice and an effective tool in structuring and ensuring the continuity of the cleaner production approach and environmental management system. In addition to the potential benefits, the cost and economic gains of the application may vary from sector to sector or depending on the facility structure (TUBITAK MAM, 2016; MAF, 2021). Although establishing and monitoring production procedures is not costly, the payback period may be short considering the savings and benefits it will provide (TUBITAK MAM, 2016; MAF, 2021).

- ***Optimising the frequency and duration of regeneration (including rinses) in water softening systems***

  Cationic ion exchange resins, which are one of the most frequently used methods for softening raw water in industrial plants, are routinely regenerated. In regeneration, pre-washing of the resin using raw water, regeneration with salt water and final rinsing processes are carried out respectively. Regeneration time is set to certain days and hours according to the hardness of the water. If the hardness is high, regeneration should be done more frequently in water softening systems.

  In regeneration processes, washing, regeneration and rinsing wastewaters are usually removed directly. However, if the washing and final rinsing waters are of raw water quality, they can be sent to raw water storage or reused in processes that do not require high water quality such as plant cleaning and green area irrigation (MAF, 2021). Regeneration wastewater has high conductivity and high salt and calcium content. For this reason, although it is not reused in areas requiring sensitive water quality, it can be reused in some industries such as yeast industry (TUBITAK MAM, 2016).

  It is very important to determine the optimum regeneration frequency in regeneration systems. Although regeneration in water softening systems is adjusted according to the frequencies recommended by the supplier or depending on the flow rate and duration entering the softening system, this frequency may also vary depending on the calcium concentration in the raw water. For this reason, online hardness measurement is applied when determining the regeneration frequency. Thus, regeneration frequencies can be optimised and excessive washing rinsing or backwashing with salt water can be avoided by using online hardness sensors.

- ***Construction of closed storage and impermeable waste/scrap sites to prevent the transport of toxic or hazardous chemicals for the aquatic environment***

  Closed and impermeable waste/scrap storage sites can be constructed in industrial facilities in order to prevent the transport of toxic or hazardous chemicals for the aquatic environment to receiving environments. This practice is already being implemented in our country within the scope of existing environmental regulations. Within the scope of the field studies carried out, a separate collection channel can be constructed in the storage areas of toxic or hazardous substances in industrial facilities and the leachate can be collected separately and prevented from mixing into natural water environments.

- ***Prevention of mixing of clean water flows with polluted water flows***

  By determining the wastewater generation points in industrial facilities and characterising the wastewater, wastewater with high pollution load and relatively clean wastewater can be collected in separate lines (TUBITAK MAM, 2016; MAF, 2021). In this way, wastewater streams with appropriate quality can be reused with or without treatment. With the separation of wastewater streams, water pollution is reduced, treatment performances are improved, energy consumption can be reduced in relation to the reduction of treatment needs, and emissions are reduced by providing wastewater recovery and recovery of valuable materials. In addition, heat recovery from separated hot wastewater streams is also possible (TUBITAK MAM, 2016; MAF, 2021). Separation of wastewater streams generally requires high investment costs, and where it is possible to recover large amounts of wastewater and energy, costs can be reduced (IPPC BREF, 2006).

- ***Implementation of time optimisation in production and arrangement of all processes to be completed as soon as possible***

  In industrial production processes, planning a raw material using the minimum number of processes until it is transformed into a product can be an effective application in terms of reducing labour costs, resource use costs, efficiency and environmental impacts. In this context, it may be necessary to revise the production processes in such a way that the minimum number of process steps is used (TUBITAK MAM, 2016). In cases where the desired product quality cannot be achieved due to some inefficiencies, inefficiency and design errors in basic production processes, production processes may need to be renewed. Therefore, in this case, the amount of resource utilisation required in the production of unit quantities of products and the amount of waste, emission and solid waste generated increases. Time optimisation in production processes is an application that can be used effectively together with other good management practices (TUBITAK MAM, 2016).

- ***Determination of the scope of reuse of washing and rinsing water***

  In industrial plants, relatively clean wastewaters such as washing-final rinse wastewaters and filter backwash wastewaters can be reused without treatment in floor washing and garden irrigation processes that do not require high water quality (Öztürk, 2014). Thus, it is possible to save between 1-5% in raw water consumption (MAF, 2021).

- ***Use of automatic hardware and equipment (sensors, smart hand washing systems, etc.) that will save water at water usage points such as showers/toilets etc.***

  Water is very important in many sectors of the manufacturing industry, both for production processes and for personnel to meet the necessary hygiene standards. Water consumption in the production processes of industrial facilities can be provided in various ways, as well as water consumption savings can be achieved by using equipment such as sensor faucets and smart hand washing systems in the water usage areas of the personnel. Smart hand washing systems provide resource efficiency in addition to water saving while adjusting the mixture of water, soap and air at the right rate.

- ***Separate collection and treatment of grey water in the facility and its use in areas that do not require high water quality (green area irrigation, floor washing, etc.)***

  Wastewater generated in industrial facilities is not only industrial wastewater from production processes, but also includes wastewater from showers, sinks, kitchens, etc. Wastewater from shower, sink, kitchen etc. areas is called grey water. Water savings can be achieved by treating these grey waters with various treatment processes and using them in areas that do not require high water quality.

Determination of wastewater flows that can be reused with or without treatment by characterising wastewater quantities and qualities at all wastewater generation points Determination and characterisation of wastewater generation points in industrial facilities

It is possible to reuse various wastewater streams with or without treatment (Öztürk,

2014; TUBİTAK MAM, 2016; MAF, 2021). In this context, filter backwash waters, TO concentrates, blowdown waters, condensate waters, relatively clean washing and rinsing waters can be reused without treatment in the same/different processes and in areas that do not require high water quality (such as facility and equipment cleaning). In addition, wastewater streams that cannot be directly reused can be reused in production processes after treatment using appropriate treatment technologies.

Membrane filtration processes are an integral part of many wastewater reuse systems. Nanofiltration (NF) and reverse osmosis (RO) filtration systems are used for industrial wastewater recovery. Microfiltration (MF) and ultrafiltration (UF) are generally used for pre-treatment of water before it goes to NF or TO (Singh et al., 2014).

- ***Storage and storage of substances (such as oils, emulsions, binders) that pose a risk in the aquatic environment and prevention of their mixing with wastewater after use***

  In industrial plants, water recovery is achieved by using dry cleaning techniques and preventing leaks to prevent the mixing of chemicals that pose a risk to the aquatic environment such as oils, emulsions and binders into wastewater streams (TUBITAK MAM, 2016).

- ***Use of closed loop water cycles in appropriate processes***

Refrigerants are chemical compounds with certain thermodynamic properties that take heat from the substances to be cooled and cool them, affecting the performance of the cooling process (Kuprasertwong et al., 2021).

Water is used as a refrigerant in many processes in the manufacturing industry and in many processes led by the product cooling process. During this cooling process, water can be reused through cooling tower or central cooling systems. If unwanted microbial growth occurs in the cooling water, it can be controlled by adding chemicals to the recirculation water (TUBITAK MAM, 2016).

By reusing cooling water in processes such as cleaning, water consumption and the amount of wastewater generated are reduced. However, the need for energy for cooling and recirculation of cooling water is a side interaction.

Heat recovery is also provided by the use of heat exchangers in cooling water. Generally, closed loop systems are used in plants where aqueous cooling systems are used. However, cooling system blowdowns are discharged directly to the wastewater treatment plant channel. These blowdown waters can be reused in appropriate production processes.

- ***Collecting rainwater and utilising it as an alternative water source in facility cleaning or in suitable areas***

Nowadays, when water resources are decreasing, rainwater harvesting is frequently preferred especially in regions with low rainfall. There are different technologies and systems for rainwater collection and distribution systems. Cistern systems, ground infiltration, surface collection and filter systems are used. Rainwater collected with special drainage systems can be used for production processes, garden irrigation, tank and equipment cleaning, surface cleaning, etc. if it meets the required quality requirements (Tanık et al., 2015).

In various examples, roof rainwater collected in industrial facilities was stored and then used inside the building and in landscape areas, resulting in 50% water saving in landscape irrigation (Yaman, 2009). Perforated stones and green areas can be preferred in order to increase the permeability of the ground and to allow rainwater to pass and absorb into the soil on the site (Yaman, 2009). Rainwater collected on building roofs can be used for car washing and garden irrigation. It is possible to recover and reuse 95% of the collected water by biological treatment after use (Şahin, 2010).

- ***Use of computer aided control systems in production processes***

Since inefficient resource use and environmental problems in industrial facilities are directly linked to input-output flows, it is essential to accurately define process inputs and outputs in specific production processes (TUBITAK MAM, 2016). This allows for the development of measures aimed at improving resource efficiency, economic performance, and environmental performance. Organizing input-output inventories is considered a prerequisite for continuous improvement. While such management practices require the involvement of technical staff and upper management, they quickly pay for themselves through the efforts of various experts (IPPC BREF, 2003). The use of measurement equipment at the process level and conducting routine analyses/measures specific to processes is necessary. To maximize efficiency from the application, utilizing computer-based monitoring systems as much as possible enhances the technical, economic, and environmental benefits obtained (TUBITAK MAM, 2016).

2.1.4 Precautions for Auxiliary Processes

BATs for cooling systems

- ***Use of air cooling systems instead of water cooling in cooling systems***

Industrial cooling systems are used for cooling heated products, processes and equipment. Closed and open circuit cooling systems can be used for this purpose, as well as industrial cooling systems using a fluid (gas or liquid) or dry air (IPPC BREF, 2001b; MAF, 2021). Air cooling systems consist of finned pipe elements, condenser and air fans (IPPC BREF, 2001b; MAF, 2021). Air cooling systems can have different operating principles. In industrial air cooling systems, the heated closed circuit coolant is cooled by air in condensers and heat exchangers (IPPC BREF, 2001b; MAF, 2021). In water cooling systems, the heated water is taken into a cooling tower and the water is cooled in drip systems. However, although water-cooled systems operate in closed circuit, a significant amount of evaporation occurs. In addition, some water is discharged as blowdown in cooling systems. Water is also lost in this way (IPPC BREF, 2001b; MAF, 2021). The use of air cooling systems instead of water in cooling systems is effective in reducing evaporation losses and also in reducing the risk of contamination of cooling water (IPPC BREF, 2001b; MAF, 2021). However, the capacity of air cooling systems is low. On the other hand, although air cooling systems do not use water, electricity is consumed for the operation of air fans. Air cooling systems have a wide range of applications. In addition, air cooling systems require a larger surface area than water cooling systems and may have higher costs (IPPC BREF, 2001b; MAF, 2021).

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